Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2013/004

ASSESSMENT OF INFORMATION ON IRISH MOSS, ROCKWEED AND KELP HARVESTS IN NOVA SCOTIA

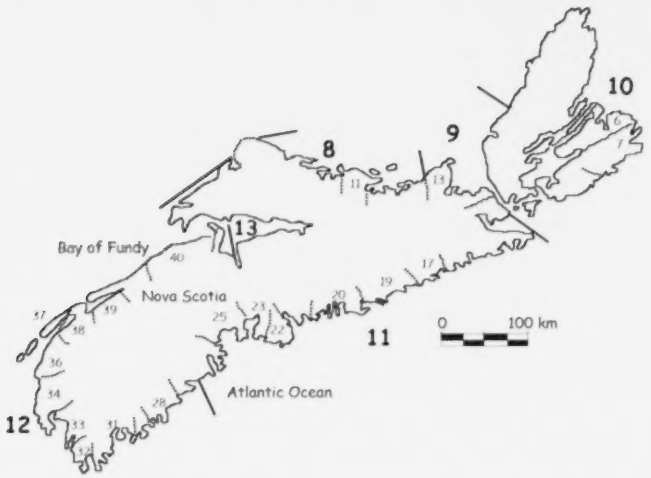

Figure 1. Nova Scotia Marine Plant Harvesting Districts (large numbers) and some Fisheries Statistical Districts (small numbers)(modified from Sharp and Roddick 1982).

Context

The harvest of attached seaweeds including Irish moss, rockweed, and kelp is currently regulated through the Fisheries Act, specifically Part IX of the Atlantic Fishery Regulations entitled 'Marine Plants'. These regulations only apply to seaweeds (algae) growing attached to rocks (except dulse). The harvest of loose drift material washed up on shore (wrack) is controlled by provincial regulations and a permit system specific to algal type and shore location.

The two most important marine plant (seaweed) fisheries in Nova Scotia are those for Irish moss (Chondrus crispus Stackh.), a 'red' seaweed, and rockweed (Ascophyllum nodosum (L.) Le Jolis), a 'brown' seaweed. Both species are primarily harvested along the rocky shores of southwest Nova Scotia. While there is currently no commercial harvest, DFO marine plant harvest licences have also occasionally been issued for 'kelp' - a mix of brown algal species most commonly including Saccharina latissima (L.) Lane, Mayes, Druehl et Saunders, S. groenlandica (Rosenvinge) Lane, Mayes, Druehl et Saunders, and Laminaria digitata (Hudson) J.V. Lamour.

Most formal stock status documentation on the seaweed harvest in Nova Scotia is at least twenty years old; therefore, in December 2011, DFO Fisheries and Aquaculture Management requested an update of the stock status of commercially harvested species of marine plants, especially of Irish moss, in the Nova Scotian portion of the Maritimes Region.

This Science Advisory Report is from the September 28, 2012, Assessment of Irish Moss, Rockweed, and Kelp in Nova Scotia. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Canada

SUMMARY

- Information on the status of Irish moss, rockweed, and kelp in Nova Scotia is provided, with science advice for ongoing management.

Irish Moss

- Irish moss *(Chondrus crispus)* populations in southwestern Nova Scotia are not considered to be under immediate threat from overharvesting or environmental factors. However, there are indications of site specific over-harvesting, and harvesting pressure appears to be increasing.
- Recommendations for protecting Irish moss populations in Nova Scotia include: establishing long term permanently closed 'control' sites for evaluating impacts on standing stocks and ecosystem effects; re-evaluating *Chondrus* standing stock for evidence of overharvest in the Lobster Bay area; enforcing the 5 mm minimum rake tine spacing throughout Nova Scotia; re-evaluating the Marine Plant Harvesting District 12 (D12) seasonal closure time to adequately protect periods of peak growth and reproductive effort, as well as seasonal habitat use of associated animals; and scientifically assessing any new harvest methods against consistent criteria prior to implementation.

Rockweed

- Advice on rockweed (*Ascophyllum nodosum*) harvest rate and canopy height is best provided at the spatial scale of a sector in Nova Scotia (sub-sector in New Brunswick).
- Advice is provided with the intent of managing recovery times of harvested rockweed and considering general ecosystem objectives related to landscape ecology for aquatic species, canopy height, and overall rockweed plant shape.
- In Nova Scotia, the present industry harvest rates of up to 25% of the harvestable biomass of rockweed have been able to maintain the commercial yield of rockweed in these harvested areas for the last 17 years. There is insufficient information or analysis from industry or third party experiments to determine whether this rate is detrimental to the habitat value that rockweed provides to associated plants and animals.
- Published studies of rockweed indicate that harvest rates of 20% allow economic recovery of harvested beds (biomass) within one year, harvest rates of 35% lead to a recovery time of up to 3 years, and harvest rates of 50% require greater than 3 years for recovery (with a pulse harvest), regardless of scale.
- Landscape ecology theory indicates that there may be benefits from managing impacts on other species and canopy height at the scale of tens of meters.
- Recommendations for protecting rockweed populations in Nova Scotia include: establishing long term permanently closed 'control' sites for evaluating impacts on standing stocks and ecosystem effects; re-evaluating *Ascophyllum* standing stock for evidence of overharvest in the Lobster Bay area; replacing the regulated minimum cutting height of 127 mm with a minimum plant cutting height of 254 mm for all parts of Nova Scotia; revisiting the current provincial rule of 15% holdfast content in rockweed landings; scientifically assessing new harvesting methods (e.g. mechanical harvesters) prior to implementation (i.e. commercial use) in Nova Scotia; re-evaluating the need for seasonal closures to adequately protect periods of peak growth and reproductive effort, as well as seasonal habitat use of associated animals.

Kelp

- Kelp populations provide important habitat and primary production on bay wide scales, and many would consider kelp beds to be very important to the nearshore ecology of Nova Scotia, particularly with their links to commercial species of fish and invertebrates.
- There are no documented large scale impacts from the harvest of kelp in Nova Scotia due to the sporadic, almost non-existent harvest at the present time, but any major increases in current harvesting would require close scrutiny, including a bay by bay assessment of standing stocks prior to harvest.
- Recommendations for protecting kelp populations in Nova Scotia include: obtaining standing stock data (including species composition) immediately prior to any harvest of kelp; surveying kelp bed habitat utilization by invertebrate and fish species prior to harvest; limiting harvesting methods to low impact hand cutting by SCUBA, including cutting plants with a sharp instrument minimally 10 cm above the "transition zone", i.e. just above the stipe / blade juncture; ensuring new harvest methods cut minimally 10 cm above the transition zone and are scientifically assessed prior to implementation; use of seasonal closures to adequately protect periods of peak growth and reproductive effort, as well as seasonal habitat use of associated animals; and to evaluate existing licence conditions for consistency with DFO ecosystem objectives.

INTRODUCTION

Seaweed populations are different from fish and invertebrate populations targeted for harvest in that natural mortality does not usually drive variations in population size to any great extent. Algal biomass is usually the result of the available space on the shore with suitable physical conditions (temperature, salinity, wave exposure, hours of desiccation at low tide, etc.). Undisturbed seaweed populations tend to be stable over long periods of time, and the natural environment does not create wide fluctuations in standing stock over the short term (years) other than storm or ice scour events in the intertidal (applicable mainly to *Ascophyllum* and *Chondrus*), or 'outbreaks' of herbivores like sea urchins in the subtidal (applicable mainly to kelp). Recruitment events tend to be predictable (e.g. spring production of conceptacles in rockweed) and do not vary widely from one year to the next. Overall, human activities cause the greatest fluctuations in algal populations, either through short term events like harvesting or deterioration in water quality, or via long term alterations such as climate change.

In December 2011, DFO Fisheries and Aquaculture Management requested an update of the stock status of commercially harvested species of marine plants in the Nova Scotia portion of the Maritimes Region. Information on the status of Irish moss, rockweed, and kelp in Nova Scotia is provided, with science advice for ongoing management.

ASSESSMENT

Irish Moss (*Chondrus crispus*)

General Biology

Chondrus populations occur low in the intertidal and into the shallow subtidal. They consist of individual plants that are either gametophytic (male or female) or tetrasporic (a plant specialized for haploid spore release, to generate new gametophytes). These two types of thalli (whole plants) are difficult to distinguish in the field, and both are indiscriminately harvested. Fronds get more branched (bushy) as they age and can reach 12 to 13 cm in length and ages up to 6 years old. The holdfasts of individual plants coalesce over time, forming extensive red crusts on rock.

New blades (gametophytic or tetrasporic) grow up from these crusts as older blades are lost (via senescence, wave action or harvesting). Hence, *Chondrus* beds tend to be perennial.

To the non-specialist, *Chondrus* is quite difficult to distinguish from the red algal species *Mastocarpus stellatus* (Stackh.) Guiry. These two species often overlap in their distributions and a harvester could inadvertently be collecting more *Mastocarpus* than *Chondrus*. The harvest of *Mastocarpus* should be avoided, as the plants are not as common as *Chondrus* and their biology is different (e.g. '*petrocelis*' tetrasporic phase for *Mastocarpus*).

Landings

The history of landings for Irish moss in Atlantic Canada is dominated by global economic forces. The initial harvests in Nova Scotia were driven by an emerging interest in carrageenan, a polysaccharide with gelling properties. As that economic interest has fluctuated, in particular with the development of harvest / culture of other species of red algal carrageenophytes in other parts of the world, so has the harvest of Canadian *Chondrus*. Until the early 1970s, *Chondrus* was the world's main source of carrageenans and eastern Canada provided 65-70% of the supply. By 1992, *Chondrus* represented only 3.8% of harvested carrageenophytes worldwide.

Harvest began in Marine Plant Harvesting District 12 (D12, see Figure 1) in the 1940s and remains the main harvest area for Nova Scotia. Landings since 1975 reflect the high harvests in response to market demand at that time. Since the late 1980s, landings have declined, with 2003 being the lowest point (Figure 2). Since 2004, however, landings have increased again, often going over the 2,000 t mark.

Landings for Marine Plant Harvesting District 11 (D11) are very small and sporadic, with only four years of landings for the period 1975 to 2009 and a peak harvest in 2006 of only 90 t. Interest in harvesting *Chondrus* has increased in this area in recent years.

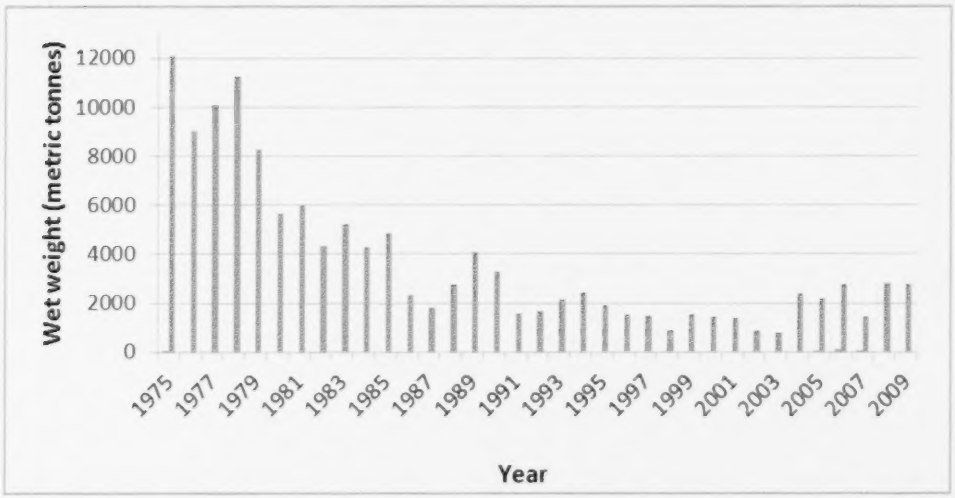

Figure 2. Nova Scotia Chondrus landings from Marine Plant Harvesting District 12 (D12). Harvest data from DFO data holdings.

Harvest Methods, Timing, and Intensity

Human activities are the most important drivers affecting long term changes in standing stock. Hence, harvest methods, timing and intensity are of primary importance in maintaining the health of the Irish moss stocks.

Irish moss is traditionally harvested by hand raking from a small boat. Hand raking while standing on shore is not recommended, as *Chondrus* is sensitive to trampling. In the early

1970s, it was noted that in some of the best *Chondrus* beds in Nova Scotia, too much raking was occurring and that it might take several years of no harvest for the beds to recover. Therefore, it was recommended that a standard rake of appropriate design and tine spacing be used for the *Chondrus* harvest.

Since these initial observations and recommendations, several studies have evaluated the efficacy of various hand rake tine spacings. It is these studies that provide the foundation for the present marine plant regulations (established in 1989) under the Atlantic Fishery Regulations, 1985, which specify a tine spacing of no less than 5 mm for the harvest of Irish moss in D12. The same minimum tine spacing is required in all other harvesting districts in Maritimes Region through licence conditions.

Drag raking (pulling rake-like trawls along the bottom with motorized boats) is commonly used to harvest *Chondrus* in Prince Edward Island. It was introduced to southwestern Nova Scotia in 1967 but was considered to be unsuitable and detrimental to Irish moss beds in this area. In the mid 1980s, drag rakes were 10% of effort in southwest Nova Scotia. The Atlantic Fishery Regulations, 1985, ban the use of drag rakes for harvesting Irish moss in some areas of Prince Edward Island, but not Nova Scotia. However, under current Maritimes Region marine plants licence conditions, harvesting is only authorized using hand-held rakes or tongs.

The time of most reproductive effort and successful spore germination for *Chondrus* in Nova Scotia is June through November. Since 1978, the harvest season for D12, as regulated through the Atlantic Fishery Regulations, 1985, has been June 7th through October 31st. However, since 2007, the opening has been delayed by Variation Order each year until the third Monday in June. The harvest season for D11 is July 1st through October 31st. In 1983, the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) analyzed harvest rates and growth rates in D12 and determined that a single annual season, with an opening date delayed to early July, would allow for the largest annual yields to be harvested. Although the harvest season for *Chondrus* in Nova Scotia is quite long (about five months), effort is high only during the first three to five weeks of the season and then drops off steadily.

Raking Irish moss with care allows the standing stock to recover within six months while over-raking produces long term damage. Studies have noted overharvesting damage to *Chondrus* beds in Nova Scotia, and have shown that it could take up to four years for bare patches in existing beds to recover to harvestable level and up to ten years for *Chondrus* to re-establish in larger barren areas.

MacFarlane (1952) reported an important phenomenon of an alternate 'stable state' where *Chondrus* is lost to coralline algal cover via over-raking. This represents a fundamental change in the state of the shore created by overharvesting and was observed as early as 60 years ago, only a decade after the *Chondrus* harvest became firmly established in Nova Scotia. This change in species composition has been described a number of times since MacFarlane's original observation.

Stock Status

In a survey completed as the commercial harvest of Irish moss was developing, MacFarlane (1952) reported *Chondrus* biomass of beds in southwest Nova Scotia that varied from 5.4 to 11.8 kg·m^{-2} (assumed to be wet weight). Although there is some evidence that MacFarlane may have been selectively sampling high density beds, in the early 1970s, other biomass estimates for *Chondrus* in southwestern Nova Scotia were 5 to 12 kg·m^{-2} wet weight, similar to MacFarlane's estimate two decades earlier. Subsequent southwest Nova Scotia studies from the mid to late 1970s and the early 1980s provided substantially lower biomass estimates compared to these earlier surveys. In 1974 and 1975, the Nova Scotia Research Foundation reported a maximum standing stock of 1.49 kg·m^{-2} (wet weight) just below chart datum, with

substantially reduced biomass at slightly greater depths in the area between Yarmouth and Shelburne.

Surveys of *Chondrus* standing stocks in the western portion of D11 in 1973 and 2008 estimate an average *Chondrus* standing stock of 3.49 kg fresh weight·m^{-2}, an average biomass that could be raked with a standard 5 mm rake of 0.9 ± 0.5 wet kg·m^{-2}, and a total harvestable biomass of just over 387 mt wet weight from Pennant Point (near Halifax) to Medway Harbour (border with D12), a coastline distance of 128 km. This is a much lower biomass per km than for the D12 areas mentioned above, as would be expected due to different environmental conditions.

Environmental Considerations

A number of natural environmental factors may affect the standing stock of *Chondrus*, including ice scour events, and repeated freezing events on successive winter low tides. If *Chondrus* is removed, the brown alga *Fucus* may establish itself and this implies that overharvesting *Chondrus* may lead to its replacement by *Fucus*, at least over the short term.

There is evidence that sea urchins may control the presence / absence of *Chondrus* on some shores and could prevent some beds from establishing on more protected shorelines.

In normal healthy populations, it appears that gametophytes dominate the population structure by at least 3:1 over the tetrasporic phase. If this ratio is lower, it indicates a population that is recovering from disturbance. Tetrasporophyte / gametophyte abundance was surveyed in four populations of *Chondrus* in Prince Edward Island and it was discovered that the site with a significantly higher proportion of tetrasporophytes was raked extensively by harvesters. There is a relatively simple chemical test to differentiate gametophytic from tetrasporic individuals in a population and, therefore, a rapid field survey could be performed to locate *Chondrus* beds recovering from the disturbance of excessive harvest activity.

Recommendations for Management

All portions of D12 and D11 are presently available to harvesters during the open season. Hence, there are no 'control' sites for an evaluation of the impacts of the harvest. Long term closed areas allow for an evaluation of harvest impacts versus environmental impacts on standing stocks. Without closed areas, these two types of impacts remain confounded. D12, and possibly D11, should have at least three sites where the Irish moss fishery is permanently closed. The closed areas do not need to be large (a small island or reef would suffice). The closed areas should be easily recognizable, well defined, and enforceable.

Lobster Bay has a long history of harvest pressure and has not been surveyed in over 25 years. There are indications in the literature that standings stocks in Lobster Bay may be lower than in the past due to chronic harvest impacts; therefore, new *Chondrus* standing stock data should be collected in the Lobster Bay area. The Lobster Bay standing stock survey should be designed to test for evidence of overharvest. The proportion of coralline algal cover (and associated animals and plants) within long-term harvested *Chondrus* beds should be compared to reference sites. The gametophyte / tetrasporophyte ratio in long-term harvested beds should be compared to reference sites using the chemical test of Brown et al. (2004).

Minor reductions in tine spacing (a reduction of a millimeter or so from 5 mm) can have profound negative harvest impacts. Tine spacing >5 mm may not have significant conservation value. Fewer *Chondrus* thalli would be removed per rake pull, and larger plants would be left behind with tine spacing >5 mm. However, the long term conservation value (if any) for tine spacing >5 mm is unknown. The 5 mm minimum tine spacing for rakes presently found in licence conditions should be enforced throughout Nova Scotia.

Drag rakes were routinely used in the past to harvest Irish moss in Nova Scotia. There are potential benthic and *Chondrus* specific impacts with the use of drag rakes that may be altered

by gear design. Mechanical harvester impacts will be specific to the gear design. Scientific assessment of any new (or previously used) harvest methods against consistent criteria prior to implementation or re-introduction would be consistent with DFO ecosystem objectives.

The present regulated start of the D12 *Chondrus* harvest (June 7th) coincides with a period of peak growth and reproductive effort. By Variation Order, the harvest currently starts slightly later, on the third Monday of June. Delaying the harvest to the D11 start time (July 1st) would offer additional protection to the D12 beds during the month of June. However, given the very broad reproductive period of *Chondrus* in Nova Scotia, delaying the harvest until July may not have significant conservation value. The D12 close time should be re-evaluated to ensure adequate protection of periods of peak growth and reproductive effort. A similar recommendation was made in 1983 by the Canadian Atlantic Fisheries Scientific Advisory Committee.

Harvest timing in terms of the highest habitat value (i.e. for juveniles of invertebrates and fish species) is not known and should be evaluated. Impacts of climate change in *Chondrus* are not known and may need to be considered in the future.

Rockweed (*Ascophyllum nodosum*)

General Biology

Ascophyllum populations are mainly intertidal but can occur in the shallow subtidal in southwest Nova Scotia. *Ascophyllum* thalli are relatively long lived (part of the reason why they outcompete *Fucus* species on many shores) and can reach 5-15 years of age. Like *Chondrus*, *Ascophyllum* thalli have holdfasts to attach to rocky substrates and these holdfasts can be very long lived, exceeding 40 years, and can be up to 7 cm in diameter. If an *Ascophyllum* frond is cut off or lost due to wave action (or ice), new fronds can grow up from the remnant holdfast. This fact is exploited by the practice of cutting *Ascophyllum* during harvest such that a stub, and the holdfast, is left behind for regeneration.

Ascophyllum is unique in Atlantic Canada due to the fact that when it is present, it tends to dominate the intertidal of the coastline it occupies, often for many kilometers. *Ascophyllum* is most abundant in southwest Nova Scotia, and tends to get less abundant along the eastern shore and northwards – probably due to increasing ice and wave exposure. Some beds do occur in Cape Breton.

The abundance of *Ascophyllum* in the intertidal indicates its relative importance as a primary producer at bay wide scales. Moreover, *Ascophyllum* is important habitat for fish, invertebrates and birds – some of which have direct commercial value. Particular care must be exercised to preserve the habitat value of *Ascophyllum* beds in the face of commercial harvest.

Landings

Ascophyllum is harvested in Nova Scotia for animal fodder, fertilizers and other specialty products. The harvest has been focused on southwest Nova Scotia (particularly Lobster Bay), and according to several sources, it began in 1959. As for *Chondrus*, the landings data for *Ascophyllum* reflect varying effort (market changes, mechanization) from year to year rather than major fluctuations in actual standing stock (Figures 3 and 4).

Following a period of more mechanisized harvesting, the period between 1993 and 2004 was marked as a reversion to hand harvesting methods. Initially, landings dropped slightly as a triennial harvest pattern was established where beds were harvested at a 50% rate and then left fallow for three years. Currently, the hand rake harvest continues in Nova Scotia and landings of the *Ascophyllum* resource have reached historical highs, in part due to expansion of harvest into new areas. An additional harvest has begun in Maine, USA, to supply the Canadian

demand, and the New Brunswick harvest continues at near capacity based upon a 17% harvest rate of accessible biomass.

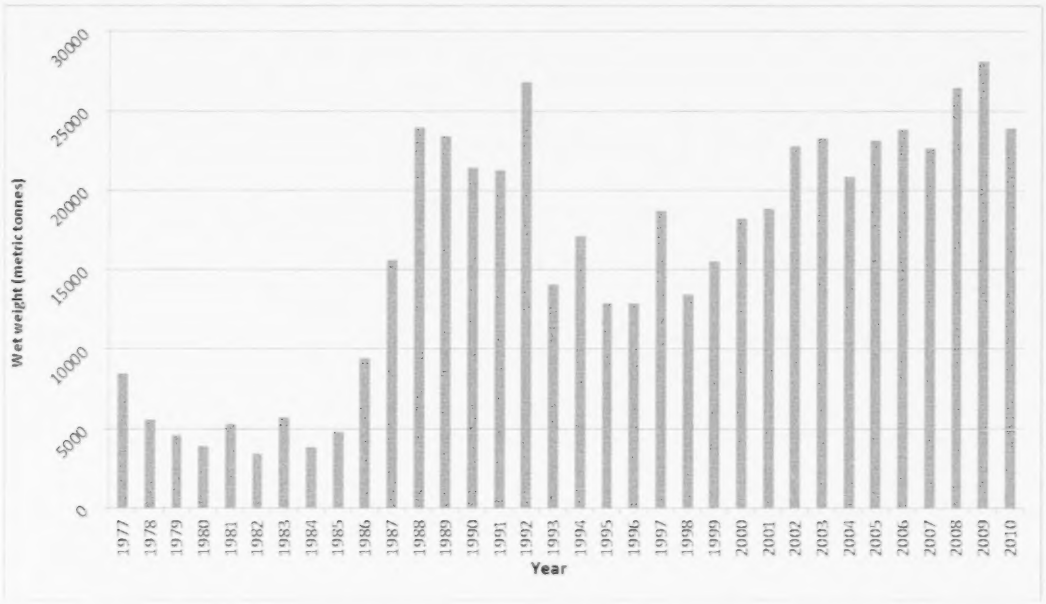

Figure 3. Nova Scotia Ascophyllum landings from Marine Plant Harvesting District 12 (D12). Harvest data from DFO data holdings.

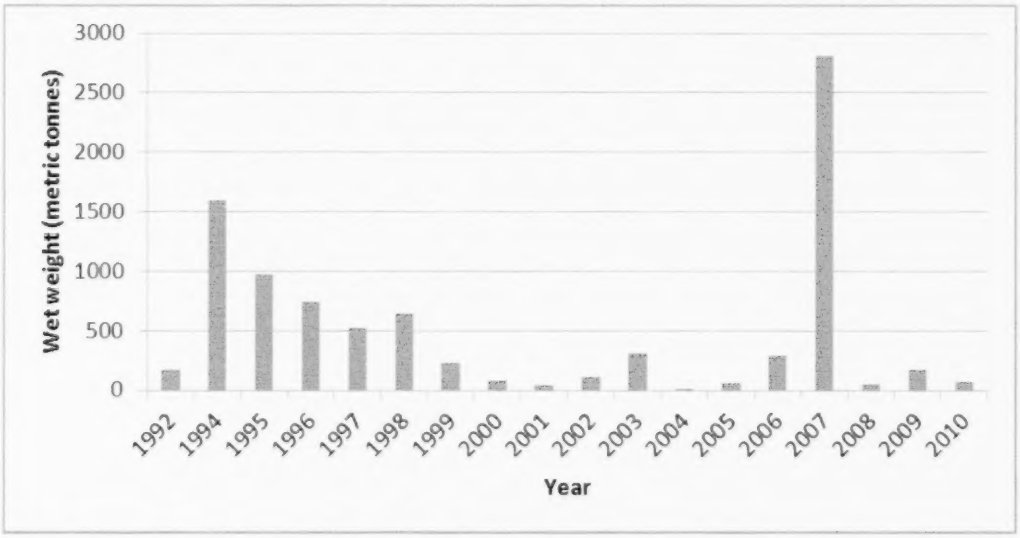

Figure 4. Nova Scotia Ascophyllum landings from Marine Plant Harvesting District 11 (D11). Harvest data from DFO data holdings.

Harvest Methods, Timing, and Intensity

Human activities are the most important drivers affecting long term changes in standing stock for *Ascophyllum*. Hence, harvest methods, timing, and intensity are of primary importance in maintaining the health of the stocks.

The *Ascophyllum* harvest began in Nova Scotia in 1959 and, for the first decade of the harvest, scythes or sickles were used to collect the plants. By the early 1970s a mechanical harvest had begun but the manual harvest was never completely abandoned. At present, hand harvesting by rake from small vessels is used for almost all of the harvest (a walk-on hand harvest is used for the remainder).

Early on, the province of Nova Scotia recognized the need for a standardized cutting height to protect the *Ascophyllum* resource. The *Nova Scotia Sea Plants Harvesting Act* specified a 127 mm (5 inch) cutting height for *Ascophyllum*. Years later, Environment Canada recommended 254 mm (10 inch) as a minimum cutting length; however, the provincial 127 mm cutting height was adopted, and this is the limit that is set in the Atlantic Fishery Regulations, 1985. The relative conservation value of the 127 mm cutting height is much less than 254 mm. There is appreciable evidence that a 254 mm cutting height significantly improves the recuperation and regrowth of *Ascophyllum* relative to 127 mm.

A variety of mechanical harvesters have been used on *Ascophyllum* beds in southwest Nova Scotia over the years with Aqua Marine harvesters accounting for 80-90% of the harvest at one time. By 1994, mechanical harvesters had ceased to operate in Nova Scotia. In 2010 and 2011, a suction type mechanical harvester was tested in an area just west of Halifax. The removal of whole plants with holdfasts attached (i.e. whole plants removed equals mortality) is significant to the management of an *Ascophyllum* harvest, especially as it applies to mechanical harvesters, because if the entire plant is removed, there is no chance for vegetative regeneration. The rate of holdfast removal in the Nova Scotia harvest of *Ascophyllum* is controlled federally through the Atlantic Fishery Regulations, 1985, which prohibit the possession of any rockweed plant to which the holdfast is attached. In provincial lease areas, the *Nova Scotia Fisheries and Coastal Resources Act* of 1996 allows up to 15% holdfast content in landings of *Ascophyllum* by weight.

Bed destruction or an overharvest of *Ascophyllum* at any one particular site may take years to recover back to a commercially viable standing stock. In the meantime, the habitat value of the *Ascophyllum* bed is reduced or lost altogether. There is evidence indicating that *Ascophyllum* has been routinely heavily harvested in southwest Nova Scotia, even well before the purported beginning of the harvest in 1959. A triennial harvest pattern, 50% removal and then a three year fallow period, was firmly established in Nova Scotia in the 1990s.

Published studies of rockweed indicate that harvest rates of 20% allow economic recovery of harvested beds (biomass) within one year, harvest rates of 35% lead to a recovery time of up to 3 years, and harvest rates of 50% require greater than 3 years for recovery (with a pulse harvest), regardless of scale.

Stock Status

MacFarlane (1952) provides one of the earliest estimates of standing stock for Nova Scotia, approximately 20 wet $kg \cdot m^{-2}$ of *Ascophyllum* in the Yarmouth – Shelburne area with a peak of about 32 wet $kg \cdot m^{-2}$ in the Mutton Islands and Tusket Wedge. These are historically high values, which are not reported subsequently, and may be due in part to MacFarlane's method of selecting the very best sites for biomass estimates, rather than more broadly representative sites. Environment Canada reported standing stocks of *Ascophyllum* in Shelburne and Yarmouth counties of approximately 7.5 to 22.5 wet $kg \cdot m^{-2}$. DFO noted that the last comprehensive survey of *Ascophyllum* standing stocks in Nova Scotia was performed in 1988 and cited a biomass of about 8 to 12 wet $kg \cdot m^{-2}$ in Lobster Bay. The province uses these numbers to the present day. The standing stock on the south shore (a less harvested area) was about 5 to 9 wet $kg \cdot m^{-2}$.

Environmental Considerations

Although *Littorina littorea* (a common snail) does not consume *Ascophyllum*, the movements of this snail may dislodge juvenile plants. Another species in this genus, *L. obtusata,* is a known herbivore of *Ascophyllum*. Grazing damage from this snail can be extensive. Grazing damage increases the probability of breakage in *Ascophyllum* thalli, especially for shorter fronds. This suggests that cutting *Ascophyllum* short for harvest will increase the loss of fronds by subsequent grazing damage.

Wave action is a major source of mortality for newly settled *Ascophyllum* zygotes. *Ascophyllum* is relatively sensitive to ice scour and usually occurs in areas with infrequent or no ice scour, while *Fucus vesiculosus* (bladderwrack) dominates in similar intertidal areas with frequent ice scour. *Ascophyllum* is also sensitive to sand scour or burial. Above 25°C, growth rates for *Ascophyllum* can decrease rapidly, and a temperature of 30-35°C is lethal (though mortality was reported at 27-28°C in Long Island Sound). Impacts of climate change on *Ascophyllum* are not known but warming may have a detrimental effect on growth and survival.

Recommendations for Management

All portions of D12 and 11 are presently available to harvesters. Hence, there are no 'control' sites for an evaluation of the impacts of the harvest. Long term closed areas allow for an evaluation of harvest impacts versus environmental impacts on standing stocks. Without closed areas, these two types of impacts remain confounded. D12, and possibly D11, should have at least three sites where the *Ascophyllum* fishery is permanently closed. The closed areas do not need to be large (a moderately sized bay or island would suffice). The closed areas should be easily recognizable, well defined, and enforceable.

Lobster Bay has a long history of harvest pressure and has not been surveyed by DFO in over 20 years, but it is surveyed by industry. There are indications in the literature that standings stocks in Lobster Bay may be lower than in the past due to chronic harvest impacts. Comparative *Ascophyllum* standing stock data should be made available for the Lobster Bay area (i.e. industry survey results should be made available and evaluated). The Lobster Bay standing stock survey should be designed to test for evidence of overharvest, including the proportion of 'short and bushy' thalli within long-term harvested *Ascophyllum* beds compared to reference sites.

Ascophyllum, and the intertidal in general, are sensitive to trampling by humans on foot or with vehicles. Although the traditional harvest is by boat with hand rake, a walk-on harvest of *Ascophyllum* does exist in Annapolis Basin and it has a history of overharvest impacts. Shore based walk-on harvest of *Ascophyllum* is considered a high risk activity at the scale of entire bays or islands, particularly in the Annapolis Basin.

Several publications indicate that a cutting height of 254 mm, previously recommended by Environment Canada in 1971, would be more precautionary than the current minimum plant cutting height of 127 mm.

A reduction to 7% holdfast incidence by weight would be more precautionary. On firm substrate with well-maintained sharp knives, it should be possible to routinely have less than 7% holdfast incidence by weight in landings (Vandermeulen, personal observation). Higher holdfast content is expected using mechanical devices rather than the hand rake method. Federal regulations restrict possession of any rockweed plant with the holdfast attached, though federal regulations do not apply on provincial marine plant lease sites, which are considered to be within provincial jurisdiction.

Mechanical harvester impacts will be specific to the gear design. Assessment of ecosystem impacts prior to implementation (for commercial purposes) would be consistent with the DFO ecosystem approach to management.

There are currently no seasonal controls on rockweed harvest. Seasonal management measures may have benefit both in terms of rockweed yield, as well as in terms of impacts on seasonal habitat use. Determining optimal timing of seasonal closures would allow managers to achieve stock productivity objectives and identify times that are of importance to other ecosystem components.

The historical (pre-2000s) harvest rates indicate that potential harmful alteration of the habitat value of *Ascophyllum* beds may have occurred in Nova Scotia, taking years to recover. High harvest levels have continued in the Annapolis Basin, and a reassessment of this area would be useful in the determination of the current status of rockweed and potential long-term impacts on habitat and ecosystem.

In Nova Scotia, the present industry harvest rates of up to 25% of the harvestable biomass of rockweed have been able to maintain the commercial yield of rockweed in these harvested areas for the last 17 years. There is insufficient information or analysis from industry or third party experiments to determine whether this rate is detrimental to the habitat value that rockweed provides to associated plants and animals.

In New Brunswick, a harvest rate of 17% of the harvestable biomass has been in place to manage rockweed since 1995. However, there is insufficient information or analysis to determine whether this harvest rate has resulted in a different level of habitat protection from rates of 20% or higher.

Kelp

General Biology

Kelp refers to a mix of brown algal species, including members of the Laminariales and Tilopteridales. A harvest of kelp would be expected to include a mix of these species. All kelp are subtidal in distribution, although some populations can extend into the low intertidal. The kelp all have a life history where a large diploid 'sporophyte' generation alternates with a microscopic haploid 'gametophyte' generation. The macroscopic sporophyte is the plant which is harvested. It consists of a holdfast, stipe, and blade. Large *Saccharina* or *Laminaria* plants can be 10 m in length or more, and weight over 2 kg. Most Nova Scotia kelp are not that long lived (up to three or four years old). The holdfasts of kelp do not coalesce as in *Chondrus* and *Ascophyllum*, and only one stipe with attached blade is associated with each holdfast. Therefore, the kelp holdfast does not offer the potential for vegetative regrowth after harvest. Indeed, leaving the kelp holdfast and stipe is also insufficient to facilitate vegetative regrowth. This is only possible if a portion of the blade remains ensuring that the transition zone (area between the stipe and blade) remains fully intact.

As for *Ascophyllum*, kelp can be important primary producers at bay wide scales. Kelp are an important food source for herbivores such as sea urchins, and provide substantial amounts of dissolved and particulate carbon for detrital food webs. Moreover, kelp provide important habitat for fish and invertebrates, and many would consider kelp beds to be very important to the nearshore ecology of Nova Scotia.

The re-establishment of a kelp bed following harvest (removal) of the entire bed may (the possibility of a gametophyte 'seedbank', these possibly longer lived than the sporophyte generation, needs to be assessed) be dependent upon settlement and growth of a new generation of gametophytes arising from the long distance transport of zoospores from other kelp beds in the bay (or farther afield). Other harvest methods, such as leaving a part of the bed, and timing, can leave plants intact for vegetative regrowth, which can assist with bed stability and possible regeneration. This dependence on transport is an important consideration that should be taken into account in the management of kelp harvest. Although a kelp bed may

look like an enduring structure, its re-establishment after harvest (or other destructive forces) is not guaranteed.

Landings

DFO does not have official landings data for kelp in Nova Scotia. Sources state that *Laminaria* was being harvested in southwest Nova Scotia in the 1930s and 1940s for the gelling agent sodium alginate. Between 1942 to 1949, estimated landings for southwestern Nova Scotia range from 3,000 - 6,000 mt wet weight per year.

Since then, records indicate only sporadic, limited harvests of kelp mainly for the health food industry 7 - 300 mt per year. Approximately seven tonnes of kelp was harvested in the Larry's River area (eastern Nova Scotia) in 1995 and Cape Canso area in 1997 related to the production of 'roe on kelp' (herring spawn on kelp blades). In 1997 and 2011, licences were issued to remove kelp from two shipwrecks in Louisbourg Harbour.

Harvest Methods, Timing, and Intensity

The harvest of kelp in Nova Scotia is essentially a harvest of entire plants because, even if extreme care was taken to hand harvest just part of the blade portion of the plants (the only method that would allow regrowth of the plants), regrowth could be slow. Significant here is the fact that regrowth is related to the season of harvest, with spring being the time when most kelp actively grow.

Various studies have evaluated the impact of hand harvesting and drag rake methods and indicate that biomass levels appear to recover to near pre-harvest levels within a year (*Saccharina latissima)* or two (*Laminaria digitata*).

A stern mounted mechanical harvester for kelp was developed in 1946 and was used in southwest Nova Scotia. A spinning auger type of mechanical harvester tested in Ledge Harbour, Lobster Bay, was evaluated, and it was estimated that the machine reduced *Laminaria longicruris* (i.e. *S. latissima*) biomass by 45% and stipe density by 68%, leaving behind truncated stipes and blades, a reduced canopy and a disturbed bottom.

In 1986, CAFSAC recommended a kelp harvest season between June and November, though this would require further study. At present, there are no seasonal controls on kelp harvest, though a limited harvest period may be, and has been in the past, prescribed through licence conditions.

There is insufficient harvest information to determine the harvest rate of kelp. CAFSAC recommended that, "to protect the reproductive potential of kelp beds, a harvest should not extend beyond 0.5 km from a spore source and a buffer zone of mature populations equivalent to the harvested area should remain abutting the harvest zone" (CAFSAC 1986). They also suggested an eighteen month fallow period between harvests, or a four year harvest cycle with two year intervals between harvesting of adjacent areas. This style of harvest would not be recommended at the present time, as recovery of the habitat value of any seaweed bed within a one year period after harvest has recently been proposed as an objective to prevent the 'Harmful Alteration' of the habitat value of the bed (Vandermeulen et al. 2012).

In 2011, a licence for kelp (the Louisbourg licence mentioned above) included the conditions that no plants will be harvested with a total length less than one meter; sharp cutting tools shall be used to cut the plant above the holdfast; no more than 30% of the bed can be harvested; an area of no more than 15 m in any direction may be harvested; and there must be a minimum un-harvested buffer of kelp between patches of 15 m. These conditions prevent a harvest that is too intense. There is no conservation value to the kelp bed itself in leaving holdfasts behind as the stub will die back in any case. However, many invertebrates and small fish are associated with kelp holdfasts, so, over the short term, it is important to preserve this aspect of the habitat

value of the original kelp plant. It would be more precautionary to harvest the blade portion above the transition zone, as is designated by provincial licence conditions in British Columbia (minimum of 10 cm of blade must be left above the transition zone; Gary Saunders, pers. comm.). Leaving 10 cm of blade could improve recovery (seasonal issue) and may also extend the integrity of the holdfast habitat.

Stock Status

The Atlantic coast of Nova Scotia was surveyed in the early to mid 1980s for sea urchins and kelp, and it was reported that kelp could be found anywhere that a rocky or hard bottom existed along with moderate or higher exposure regimes (e.g. wave impacted shores). Studies on St. Margaret's Bay determined that the bulk of algal biomass in the bay was in subtidal kelp, *L. digitata, L. longicruris* (now *S. latissima*) (the proportion of the previous two attributable to *S. groenlandica* represents a significant gap in knowledge as this species went overlooked at that time; see McDevit and Saunders 2010), and *Agarum*.

Early surveys in southwest Nova Scotia estimated *Laminaria* spp. standing stocks of 12 to 29 $kg \cdot m^{-2}$ wet weight in the best beds and 11 to 52 mt per hectare (26 to 128 mt per acre) of *Laminaria* spp. in the area of Yarmouth / Shelburne. Cape Sable Island was reported one of the best *Laminaria* producing areas. Other studies have evaluated kelp biomass in various kelp beds in St. Margaret's Bay and southwest Nova Scotia and observations range from 3-17 $kg\ m^{-2}$.

Environmental Considerations

Kelp are susceptible to a wide variety of herbivores including sea urchins (which can completely destroy kelp beds in Nova Scotia for long periods of time), and snails such as *Lacuna vincta*, which can also cause significant damage at the bed scale. The lower depth limit of kelp beds may be controlled by the presence of sea urchins. Urchins are able to stay attached to the bottom in deeper, less turbulent waters, grazing back kelp in this zone. In shallower waters, however, the effects of wave action are more pronounced and urchins cannot 'hang on' in this zone, allowing kelp beds to flourish in the more turbulent shallows.

It has been noted that the introduced bryozoan *Membranipora membranacea* can harm kelp by covering the blade, and the invasive green alga *Codium fragile* ssp. *tomentosoides* can interfere with kelp bed dynamics. *Membranipora* can cause extensive defoliation of *Laminaria / Saccharina* and can also negatively impact spore output from Nova Scotian *Saccharina latissima*.

Urchins prefer kelp over *Codium* and could preferentially graze kelp away, leaving *Codium* behind. Once *Codium* is established, it can prevent recolonization by kelp. A different assemblage of macro-invertebrates is associated with a canopy of *Codium* versus *Laminaria / Saccharina*.

Recommendations for Management

Because of the short life-span of kelp, assessment of standing stock (including species composition) would need to be conducted immediately prior to any harvest of kelp, even if the kelp bed was harvested in a previous year. A seasonal survey of invertebrate and fish species utilizing the kelp bed prior to harvest would fulfill this requirement. Hand cutting by SCUBA is recommended as a 'low impact' harvest method, especially if cut minimally 10 cm above the "transition zone" (stipe / blade juncture). An assessment of kelp survival with this harvesting strategy (i.e. leaving 10 cm of blade) should also be seasonally assessed, as this measure may have more efficacy if implemented during the kelp's active growth period (typically spring, but which may differ for the divergent Nova Scotian species currently included in the term 'kelp').

Any gears not currently in use would have to be assessed for their ecological impacts prior to implementation (i.e. commercial use). Consistent criteria (e.g. ability to cut above the transition zone) for evaluation would need to be developed.

CAFSAC made a recommendation in 1986 for a closed winter harvest time. However, there are currently no regulated seasonal controls for kelp. Maximum growth of kelp occurs in spring. The seasonality of harvest (should it occur) would need to be investigated both in terms of yield and habitat impacts.

The following management measures have been included as conditions of licence for a number of years, but the conservation effectiveness of these measures requires evaluation: no plants will be harvested with a total length less than one meter; sharp cutting tools shall be used to cut the plant minimally 10 cm above the transition zone; no more than 30% of the bed can be harvested (20% in British Columbia); an area of no more than 15 m in any direction may be harvested; and there must be a minimum 15 m un-harvested buffer of kelp between harvested patches. Additionally, if the kelp bed was previously harvested, and the standing stock has not returned to pre-harvest levels after one year, no further harvest of the bed should be allowed.

Sources of Uncertainty

DFO Data Holdings for Irish moss harvest data start in 1975, just before federal harvesting regulations came into effect in 1978. The 2010 harvest season saw the introduction of voluntary landings data sheets to be filled out by individual harvesters. These data were incomplete but used by DFO as the official landings data for 2010.

DFO Data Holdings for *Ascophyllum* begin in 1977, decades after the establishment of the fishery. There is some uncertainty in the landings values embedded in the traditional DFO landings record (published values from other authors do not match the DFO Data Holdings). Several publications provide landings data for the early years of the harvest. The reliability of some of the early landings data is uncertain; however, there is greater management value in including them in analyses rather than ignoring them.

All portions of D12 and 11 are presently available to *Chondrus* and *Ascophyllum* harvesters during the open season, and there are no 'control' sites for an evaluation of the impacts of the harvest versus impacts from other factors (e.g. storms, environmental factors).

A number of species are grouped together under the category of "kelp." There is a risk that incorrect assumptions about kelp species composition, ecological and biological characteristics would lead to inappropriate management advice.

There are expected to be effects of climate change on Irish moss, rockweed and kelp, which would have consequences for management, but these are not well understood.

Invasive species, such as *Membranipora membranacea* and *Codium fragile*, can also have an impact on marine plants and their habitats. *Heterosiphonia japonica* Yendo, is an introduced red algal species that can overwhelm the bottom and 'smother' other biota. It has been found in New England and appears to be moving north.

CONCLUSIONS AND ADVICE

Irish Moss

As a whole, Irish moss (*Chondrus crispus)* populations in southwestern Nova Scotia are not considered to be under immediate threat from overharvesting or environmental factors. However, there are indications of site specific overharvesting, and harvesting pressure appears to be increasing.

Recommendations for protecting Irish moss populations in Nova Scotia include: establishing long term permanently closed 'control' sites for evaluating impacts on standing stocks and ecosystem effects; re-evaluating *Chondrus* standing stock for evidence of overharvest in the Lobster Bay area; enforcing the 5 mm minimum rake tine spacing throughout Nova Scotia; re-evaluating the Marine Plant Harvesting District 12 (D12) seasonal closure time to adequately protect periods of peak growth and reproductive effort, as well as seasonal habitat use of associated animals; and scientifically assessing any new harvest methods against consistent criteria prior to implementation.

Rockweed

At the meeting, it was agreed that advice on rockweed (*Ascophyllum nodosum*) harvest rate and canopy height is best provided at the spatial scale of a sector in Nova Scotia (sub-sector in New Brunswick). Advice is provided with the intent of managing recovery times of harvested rockweed and considering general ecosystem objectives related to landscape ecology for aquatic species, canopy height, and overall rockweed shape. Landscape ecology theory indicates that there may be benefits from managing impacts on other species and canopy height at the scale of tens of meters.

In Nova Scotia, the present industry harvest rates of up to 25% of the harvestable biomass of rockweed have been able to maintain the commercial yield of rockweed in these harvested areas for the last 17 years. However, there is insufficient information or analysis from industry or third party experiments to determine whether this rate is detrimental to the habitat value that rockweed provides to associated plants and animals. Published studies of rockweed indicate that harvest rates of 20% allow economic recovery of harvested beds (biomass) within one year, 35% harvest rates lead to a recovery time of up to 3 years, and harvest rates of 50% require greater than 3 years for recovery (with a pulse harvest), regardless of scale.

Recommendations for protecting rockweed populations in Nova Scotia include: establishing long term permanently closed 'control' sites for evaluating impacts on standing stocks and ecosystem effects; re-evaluating *Ascophyllum* standing stock for evidence of overharvest in the Lobster Bay area; replacing the regulated minimum cutting height of 127 mm with a minimum plant cutting height of 254 mm for all parts of Nova Scotia; revisiting the current provincial rule of 15% holdfast content in rockweed landings; scientifically assessing new harvesting methods (e.g. mechanical harvesters) prior to implementation (i.e. commercial use); re-evaluating the need for seasonal closures to adequately protect periods of peak growth and reproductive effort, as well as seasonal habitat use of associated animals. As well, whole bay or whole island shore based walk-on harvest of *Ascophyllum* is considered a high risk activity due to trampling damage to the plants themselves and associated biota plus the relative ease of attaining very high harvest rates, particularly in the Annapolis Basin where a harvest rate of 50% or much more has existed for decades, prompting at least one full closure of the basin.

Kelp

Kelp populations provide important habitat and primary production on bay wide scales, and many would consider kelp beds to be very important to the nearshore ecology of Nova Scotia, particularly with their links to commercial species of fish and invertebrates.

There are no documented large scale impacts due to the harvest of kelp in Nova Scotia due to the sporadic, almost non-existent harvest at the present time, but any major increases in current harvesting would require close scrutiny, including a bay by bay assessment of standing stocks prior to harvest.

Recommendations for protecting kelp populations in Nova Scotia include: obtaining standing stock data (including species composition) immediately prior to any harvest of kelp; surveying kelp bed habitat utilization by invertebrate and fish species prior to harvest; limiting harvesting methods to low impact hand cutting by SCUBA, including cutting plants with a sharp instrument minimally 10 cm above the "transition zone", i.e. just above the stipe / blade juncture; ensuring new harvest methods cut minimally 10 cm above the transition zone and are scientifically assessed prior to implementation; use of seasonal closures to adequately protect periods of peak growth and reproductive effort, as well as seasonal habitat use of associated animals; and to evaluate existing licence conditions for consistency with current DFO ecosystem objectives.

Other Issues

Issues with the flow of official harvest information from industry, to the province, and to DFO need to be resolved such that this information can be used appropriately for stock status assessment purposes. Better information on harvest effort would assist with interpretation of catch information by analyzing catch per unit effort trends. Collection of fishery independent information also contributes to more effective evaluation of stock status.

Dulse has not been included in this assessment, as it is not currently regulated by the *Fisheries Act*; however, there is a dulse harvest, and, thus, there is a need to evaluate this stock in the future. As other marine plant species are being considered for small-scale harvest, further consideration should be given to development of criteria for when assessments of these species/harvests might be appropriate.

SOURCES OF INFORMATION

This Science Advisory Report is from the September 28, 2012, Assessment of Irish Moss, Rockweed, and Kelp in Nova Scotia. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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